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THE CENTER FOR ADVANCED SYSTEMS AND ENGINEERING (CASE)

SYRACUSE UNIVERSITY

JANUARY 2012

FINAL TECHNICAL REPORT

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INFORMATION DIRECTORATE

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Center for Advanced Systems and Engineering (CASE), for and on behalf of Syracuse University, has provided the services for managing the Air Force Research Laboratory Information Directorate Visiting Faculty Research Program and Summer Faculty Fellowship Program. The CASE placed highly qualified and motivated faculty members and graduate students (M.S. and Ph.D.) in science, technology, engineering and mathematics (STEM) disciplines as well as other recognized technical and newly emerges interdisciplinary areas to provide intellectually stimulating summer environment for the visitors to have enriched and rewarding experiences. The CASE, a New York Center for Advanced Technology supported by the New York State Office of Science, Technology, and Academic Research (NYSTAR), has a long history of collaboration with the AFRL/RI. Through this endeavor, CASE supported administrative requirements for faculty members' contracts including five contract extensions and one contract spring-extension.

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1. INTRODUCTION

The Center for Advanced Systems and Engineering (CASE), for and on behalf of Syracuse University, has provided the services for managing the Air Force Research Laboratory Information Directorate (AFRL/RI) Visiting Faculty Research Program (VFRP) and Summer Faculty Fellowship Program (SFFP). The CASE placed highly qualified and motivated faculty members and graduate students (M.S. and Ph.D.) in science, technology, engineering and mathematics (STEM) disciplines as well as other recognized technical and newly emerged interdisciplinary areas in the Air Force Research Laboratory Information Directorate. These faculty members and graduate students worked with the staff of the Information Directorate to advance the research base in areas of research of interest to the Air Force. The goal of the program is to provide intellectually stimulating summer environment for both the visitors and staff of the Information Directorate and for the visitors to have enriched and rewarding experiences.

The CASE, a New York State Center for Advanced Technology supported by the New York State Office of Science Technology and Academic Research (NYSTAR), has a long history of collaboration with the AFRL/RI. Through this endeavor, CASE supported administrative requirements for faculty members' contracts including fourteen summer appointments and eight fall extension grants. Abstracts of the research performed during the summer fellowships and extension grants follow.

2. FACULTY & RESEARCH AREAS

2010 Summer Professors

Howard Blair, Syracuse University – Relativistic Quantum Information

We investigated and performed a more detailed characterization of the gap between Gleason correlations and the full set of no-signaling correlations for quantum systems. We found additional requirements on measurements and constraining physical principles that will narrow or eliminate the gap. In the process of seeking these additional requirements and physical principles we identified opportunities to exploit what we found to aid in the development of realistic quantum information-processing devices.

Kyoung-Don Kang, State University of New York at Binghamton – Context-Aware Adaptive Real-Time Information Dissemination

This research aims to provide airborne real-time information dissemination services to support the prioritized publish/subscribe/query model of the Joint Battlespace Infosphere in net-centric environments. By supporting real-time information dissemination in a context-sensitive fashion, our research is expected to produce significant operational benefits. For example, our approach can report immediate threats beyond the line of sight to the subscribed ground forces in a timely manner. Also, our approach can provide situational information involving, for example, moving targets and spatio-temporal context information in the AOI, to C2 nodes and ground forces in a timely, balanced way. In terms of technology, this work will significantly advance the current state-of-art by developing:

- Contextual QoS metrics
- Scheduling and service differentiation schemes
- Predictive as well as reactive methods to dynamically adapt the dissemination rate considering potentially varying wireless link conditions At the same time, we thoroughly evaluate the performance and potential mission effectiveness of the proposed approaches and baselines. Despite the importance, related work on contextual QoS support for real-time information dissemination and in-depth evaluation of the supported QoS and mission effectiveness is scarce in the areas of real-time computing and wireless sensor networks. Overall, our work has substantial impacts in terms of expected operational benefits and technological advances.

Xiaohua (Edward) Li, State University of New York at Binghamton – Anti-Jamming Performance of Cognitive Radio Networks

Our major focus is the security of cognitive radio networks. Specifically, we address one of the major concerns of cognitive radios when used for secondary spectrum access, i.e., the anti-jamming performance. This is related to both the jamming capability of the cognitive-radio-based jammers and the anti-jamming capability of the cognitive radio networks. As many people have recognized, cognitive radio technology can potentially make the jammers more powerful in conducting jamming attacks due to the flexible physical-layer and MAC-layer function. In

contrast, cognitive radio networks may become more susceptible to jamming attacks because of some unique requirements in the physical-and MAC-layer, such as the requirement of channel vacating when detecting any primary user signals. On the other hand, the capability of hopping among many channels gives a unique advantage of designing new anti-jamming techniques for cognitive radio networks. Therefore, the anti-jamming research in cognitive radio networks is a new and critical task, especially for military communications. In this report, we first outline some unique properties of cognitive radio networks which make the anti-jamming research a challenging but interesting research topic. Then we setup the model of the cognitive radio networks and cognitive-radio-based jammers. We show that the research in cognitive radio anti-jamming is different from conventional anti-jamming research, and it should be an inherently cross-layer design task. Specifically, we show that Physical-layer and MAC-layer parameters are important for anti-jamming design. We analyze various jamming attack strategies which spend various powers in order to jam various transmission slots of the cognitive radio networks. We derive the average throughput and the jamming probability under such jamming attacks. Simulations were conducted to verify our analysis results. The results will show that the best jamming target (and thus the most susceptible area of the cognitive radio networks) is the spectrum sensing (channel sensing) and the channel switching procedure. Anti-jamming design is a challenging task, as some smart jammers can easily jam the cognitive radio network communications. Based on our analysis and simulation results, we outline some general design rules to enhance the anti-jamming performance of cognitive radio networks, and outline some important research tasks for the near future. Two conference papers are in the drafting based this research results, and one journal paper drafting is in our plan.

Sanjay K. Madria, Missouri University of Science and Technology – A Caching Model to Improve Data Accessibility in Mobile Ad-hoc Networks

Simulation will be done using a group of mobile hosts and we will design experiments to measure the time for the network to cluster. Performance metrics will include average response time (ART) of a query, data availability (DA) and traffic (TR) for cache allocation. We observe the effect of the following parameters on our performance metric (a) variations in the number of MPs (b) variations in the workload skew (c) effect of changing reallocation period (d) effect of write frequency on the performance metric. In addition, the above important parameters will be experimented in conjunction with the following: network partition frequency (0 to some N), length of partition time (0 to some period T), and disconnection time of nodes. Additional constraints such storage, bandwidth, peers profile will be integrated during experiments. We also simulate mobility of mobile hosts under different mobility models and calculate their ability to provide guaranteed service for a request. The results will be studied by plotting a graph between the bandwidth usage and response time per query. When the size of the cluster increases, more queries are submitted per unit time; hence we expect a slight increase in the response time, which can be compensated by caching more copies in the cluster to bring the response time within the threshold. This experiment will help in identifying the optimal size of the clusters and the number of cached copies needed. We will also evaluate the traffic patterns based on the average number of hops under different conditions in accessing cached data. We will compare this with results of other existing approaches. We expect through in our approach there will be significant improvement in data accessibility with reduction in network traffic and optimal use of the bandwidth.

Kamala Monisha Mahanta, State University of New York at Oneonta – Graphene Nano-Technology Research

Nano-scale miniaturization of electronics is pushing CMOS technology to its physical and geometrical limits. At this juncture, Graphene, which is a monolayer of carbon atoms packed into a two-dimensional honeycomb lattice and has unique characteristics, has attracted a great deal of interest from the nanotechnology research group. Although capable of offering the exceptional properties of carbon nanotubes (CNTs) which are rolled up graphene sheets, graphene has no band gap which makes it only metallic and unsuitable for devices. The solution to the zero band gap problem of graphene has been found in Graphene nanoribbons (GNRs) which are strips of graphene patterned in such a way that band-gap control is achieved to make it suitable for nano-electronic devices. While carbon nanotubes (CNTs) offer the most promises for nano-electronics, GNRs offer the major advantage of being much more straightforward in the fabrication process. Recent breakthroughs in fabrication and characterization of GNRs have generated a lot of interest in the potential of GNRs as interconnects and devices since both metallic and semi-conductor behaviors are present in GNRs. Fabrication of electronic circuits consisting of both transistors and interconnects on the same continuous graphene sheet has also been proposed; this approach carries the potential for the elimination, in part, of the need for metal-to-graphene contacts.

Tommaso Melodia, State University of New York at Buffalo – Exploiting Cooperation in Cognitive Ad Hoc Radio Networks

Defined Cognitive Network Testbed throughput maximization is a key challenge in cognitive radio ad hoc networks, where the availability of local spectrum resources may change from time to time and hop-by-hop. To achieve this objective, cooperative transmission is a promising technique to increase the capacity of relay links by exploiting spatial diversity without multiple antennas at each node. This idea is particularly attractive in wireless environments due to the diverse channel quality and the limited energy and bandwidth resources. In this report, decentralized and localized algorithms for joint dynamic routing, relay assignment and spectrum allocation in a distributed and dynamic environment are proposed and studied. A cross-layer protocol to implement the joint routing, relay selection and dynamic spectrum allocation algorithm is also introduced, and its performance is evaluated through simulation. Performance evaluation results show that the proposed protocol achieves much higher throughput than solutions that do not rely on cooperation.

Vladimir V. Nikulin, State University of New York at Binghamton – Wave Front Sensing and Coherence Estimation in Free-Space Quantum Communication Links

Optical communication in general has proven to be the lowest cost and most scalable technology for keeping up with increasingly large bandwidth demands. Optical links are characterized by absence of channel contention, low probability of detection and interception, and resistance to jamming [1] – [3]. A simulation algorithm developed in this project has provided a model for the effects of atmospheric turbulence on a free-space optical link between RRS and Stockbridge. We also developed a mathematical model of a wave front sensor, which performs phase retrieval

by measuring intensity distribution in two pre-defined planes. While the algorithm showed generally acceptable performance, its speed of convergence greatly depends on the choice of initial conditions. It was observed that under weak turbulence conditions, which result in mild wave front distortions, the adaptation process can sometimes take longer compared to a case when stronger turbulence is encountered. The reason for this is a very complex optimization, which is required to perform phase retrieval. Since any approach derived from Gerchberg-Saxton method falls in the class of direct search methods, it is subject to converging to local minima, which may not always give acceptable phase estimation error. However, the proposed approach can be used to successfully calculate many instantaneous realizations of the optical wave front and aid in coherence estimation in optical links.

Jing Peng, Montclair State University – A Multi-Armed Bandit Approach to Information Fusion

A fusion algorithm based on adaptive boosting has been developed recently. Experimental data indicate that the algorithm is very promising in terms of its robustness against noise. However, no rigorous theoretical result regarding its performance has been established. In this work, we cast the fusion algorithm within the adversarial multi-armed bandit framework. As a result, we are able to develop a novel variant of the fusion algorithm and establish a rigorous mathematical statement about its convergence. We have developed an efficient fusion algorithm with performance guarantees in order to address these two fundamental problems. Our technical approach rests on the idea of boosting. Boosting provides a principled framework in which to build high strong classifiers and represent many types (sensors) of data. Each data type provides a partial view about a potential target, i.e., extracting a specific type of information from a given sensor. Boosting provides a mechanism for effectively representing all of the information available, whereby the fused information can then be exploited by classifiers. As a result, ensemble methods can be extremely useful for making inferences about potential wide area targets from multiple sensors.

Qinru Qiu, State University of New York at Binghamton – A Neuromorphic Approach for Intelligent Text Recognition

Modern image processing software performs image detection and pattern recognition with fairly high accuracy given the condition that the input image is clean and fully observable. Pattern recognition becomes extremely difficult, if not impossible, when the image is partially obscured or even partially missing. Compared to computer-based image processing algorithms, the human brain exhibits extraordinary ability for pattern recognition in noisy environments because it generates anticipations based on the context of the input and knowledge of the problem. This paper presents an Intelligent Text Recognition System (ITRS) that mimics the human information processing procedure to fill in the missing or damaged text by considering the word level and sentence level context. The system is built upon two cognitive computing models, the Brain-State-in-a-Box (BSB) Attractor Model and the Cogent Confabulation Model. The former performs character detection and later performs word and sentence completion. Given a scanned text image where each character is 15-by-15 pixels large, experimental results show that, when 20% of the character images are damaged by a 1-pixel-wide horizontal scratch running through the center of the image where most of the information to distinguish amongst various characters is found, the ITRS recognizes complete sentences at 92% accuracy. When 60% of the character

images are damaged by a 3-pixel-wide horizontal scratch located at the center, the ITRS recognizes sentences at 64% accuracy. Furthermore, when 10% of the characters are completely occluded, the ITRS recognizes sentences and words at more than 60% and 95% accuracy respectively. When the occluded characters increase to 30%, the sentence accuracy drops to 20% and the word accuracy drops to 85%.

Hassan Rasheed, University of Florida - Cyber Security Research in Support of the CyberBat Program

An implementation of a traffic analysis tool developed as a plugin for the Wireshark network protocol analysis platform is described. Effective analysis tools are an important part of advancing the state-of-the-art in many fields such as network forensics and traffic analysis. We describe a plugin extension for the Wireshark network protocol analysis suite that provides the capability to detect and label traffic to and from known adservers. We describe an implementation aimed at estimated server availability. The field of security metrics has garnered increase attention in recent years as companies and organizations strive to assess the actual value that security investments have on overall IT infrastructure. One such metric is server availability. Although widely used, it is often calculated simply while neglecting the multiple individual measures that influence availability. The goal of this project is to develop a set of libraries that can analyze network traffic at the protocol and produce robust availability metrics for servers. We examine the subject of auditing in cloud computing environments. Cloud computing has recently grown into prominence as one of the most attractive computing paradigms for businesses to cut costs while maintaining the technology infrastructure to meet their needs. Despite its attractiveness, however, many remain reserved due to concerns about the security and auditability of cloud environments. We introduce the paradigm of cloud computing and then study two different types of audit: audit against industry security standards and audit of resources provided by the cloud service provider.

Shangping Ren, Illinois Institute of Technology – Beyond Byzantine Faults: Addressing the Dependable Cyber-Physical Systems Challenge

Networked computers reside at the heart of systems on which many people now rely, both in critical national infrastructures and in private enterprises. Today, many of these systems are still far too vulnerable to cyber attacks that can inhibit their functioning, corrupt important data, or expose private information. “Fault-tolerance” and “attack tolerance” while maintaining system liveness have become key research issues in the cyber defense research community. This year’s summer research has been mainly focused on two areas: (1) how to optimally allocate available resources to tolerate cyber attacks and improve networked computer systems’ dependability; and (2) how to efficiently and effectively identify fail-stop faults in cyber-physical systems. We have obtained good research results in these two areas over the summer. In particular, to tolerate faults and cyber attacks, we have developed an algorithm that can optimally utilize available resource to enhance existing systems with maximized dependability. This work has already been submitted to a conference.
In addition, we have found that rather than using static analysis to predict worst case execution time (WCET) and then using the WCET to decide component failures, which requires detailed information about the system, we can use available runtime data to adaptively estimate next

timeout values. The runtime approach is more effective in identifying fail-stop faults than the static approach when detailed information about the system is known, as is required by static analysis approach. We are in the process of submitting the result for publication in a conference or a journal.

Jason Rogers, SUNYIT, Basic Research, Development and Emulation of Derived Models of Neuromorphic Brain Processes to Investigate the Computational Architecture Issues They Present

Work pertaining to the basic research, development and emulation of derived models of Neuromorphic brain processes to investigate the computational architecture issues they present. Models will include but are not limited to sensory inputs, training, learning, perception, attention and association while utilizing our present basic building block referred to as the "minicolumn". Confabulation theory will also be utilized as a higher- level functionality technique.

Qing Wu, State University of New York at Binghamton – Device Modeling, Software and Hardware Optimizations in Neuromorphic Computing

In this report, we present summer work in three research areas of neuromorphic computing. In the research project of advanced reconfigurable memristor circuit, new models based on Verilog-A was developed for simulating memristor devices with industry-standard EDA (Electronic Design Automation) tools. Comparing to the previous models which are written in Matlab and LTSpice, the new Verilog-A models work with HSPICE and Spectre, making it possible to design and simulate memristor-based integrated circuits in Synopsys or Cadence design flow. Additional work has been done on improving the robustness of the device models, as well as designing and simulating basic memristor circuits. For the CyberCog chip project, we present wire delay analysis for long bus wires in the IBM 65nm 10LPe technology. The analysis procedure includes creating layout designs for different settings of wire length, wire width and wire spacing, extracting distributed RC network into SPICE, simulating and measuring the delay values. The analysis results will be used as guidance for bus wiring of the CyberCog chip design.

Lei Yu, State University of New York at Binghamton – Scalable Reinforcement Learning for Robust Command and Control: Improving Generalization in Continuous Action Spaces

Classical reinforcement learning techniques become impractical in domains with large complex state spaces. The size of a domain's state space is dominated by the number of features used to describe the state. Fortunately, in many real-world environments learning an effective policy does not usually require all the provided features. In this paper we present a feature selection algorithm for reinforcement learning called Incremental Feature Selection Embedded in NEAT (IFSE-NEAT) that incorporates sequential forward search into neuroevolutionary algorithm NEAT. We provide an empirical analysis on a realistic simulated domain with many irrelevant and relevant features. Our results demonstrate that IFSE-NEAT selects smaller and more effective feature sets than the best known alternative approach, FS-NEAT, and superior performance characteristics as the number of available features increases.

3. CONTINUING RESEARCH PROJECTS

2010 Extension Grants

Kyoung-Don Kang, State University of New York at Binghamton – Active Queue Management via Event-Driven Feedback Control

Real-time information dissemination aware of quality of service (QoS) is critical to provide the right information to the right users at the right time in net-centric environments by information management services, such as those provided by the Air Force Research Laboratory (AFRL) Joint Battlespace Infoshpere (JBI). In this report, we focus on information dissemination between varieties of systems ranging from airborne sensors such as unmanned aerial vehicles (UAVs) to command and control (C2) nodes or ground forces, for example, to support visual target tracking or reconnaissance. In the future combat systems, platoons will use micro air vehicles that cooperate with each other to find potential threats beyond the line of sight, such as threats over the next hill. Or, a group of aircraft may acquire and disseminate reconnaissance information from a remote area of interest (AOI), e.g., Kabul in Afghanistan, to C2 nodes or ground forces to improve the situation-awareness for mission planning. In order to provide adequate QoS to intelligence, surveillance, and reconnaissance (ISR) applications in net-centric environments, it is critical to ensure that information publishers, such as UAVs, disseminate the most important information first to the subscribers, such as the other aircraft or ground forces, in a timely manner despite varying network conditions. Also, it is important to efficiently utilize the highly constrained and potentially varying available wireless bandwidth.

Sanjay K. Madria, Missouri University of Science and Technology – MELOC: Memory and Location Optimized Caching Model for Mobile Ad Hoc Networks

Applications running over Mobile Ad-hoc Networks (MANETS) are increasing day by day within both social and military domains that require faster access to data. Caching is the common technique to improve efficiency of data access in MANETS where users communicate among themselves using small devices connected by resource constraint network. In some of these applications multiple cache locations are not desirable due to limited memory and security concerns. At the same time, hops to the data must also be optimized. That is, in such cases, reducing the number of caches and finding optimal cache locations should not affect the performance efficacy of data access. Existing cooperative caching approaches are deficient in finding the optimal cache location to reduce the number of copies. In this paper, we design and evaluate a caching scheme within a broker-based architecture to improve data access in mobile ad-hoc networks, which eventually reduces the number of caches by identifying optimal cache locations. Comparison with one such recent caching scheme showcased a significant improvement in performance. We also evaluate the impact of this scheme with respect to average hops and average roundtrip delay through extensive simulation.

Tommaso Melodia, State University of New York at Binghamton – Exploiting Cooperation in Cognitive Ad Hoc Networks

We studied and proposed decentralized and localized algorithms for joint dynamic routing, relay selection, and spectrum allocation in cooperative cognitive radio ad hoc networks. We have shown how the proposed distributed algorithms lead to increased throughput with respect to non-cooperative strategies. The discussion in this paper leaves several open issues for further research. First, we aim at deriving a theoretical lower bound on the performance of the proposed algorithm. Furthermore, we evaluate the performance of the algorithm in conjunction with a congestion control module. Finally, we implement the proposed algorithm on a testbed based on URSP2 [32] and GNU Radio [33].

Vladimir Nikulin, State University of New York at Binghamton – Implementation of a Prototype Wave Front Sensor for Characterizing Free-Space Quantum Communication Links

Mobile optical links offer secure communication channels with low probability of interception (LPI) and detection (LPD). However, based on practical issues, such as antenna size and pointing errors, there is still a risk of unauthorized access to information, which can be significantly minimized with data encryption. One practical approach to enhancing security via encryption is to exploit the quantum noise of light using a novel modulation format, called Alpha-Eta, which adds true randomization to a traditional cipher. Such quantum data encryption protocols enable better security than alternative systems based solely on mathematical complexity. Just like any laser communication technology, Alpha-Eta links suffer from wave front distortions, and special attention must be paid to integrity of the phase-encrypted signals. A potential problem exists when a portion of the wave front incident on the receiving aperture can be represented as a collection of plane waves with relative phase shifts. Just a half wave of variation across the receiving aperture results in wave front distortion of the collected wave front having a relative phase shift of π, which has been shown to hinder signal decryption. Within the scope of the 2010 VFRP program, we were developing a technique for measuring phase distribution of encrypted signals. This knowledge can be very useful for designing the optical front ends that would make the decryption process less susceptible to spatial phase variations. Analysis of atmospheric spectral models and modeling of dynamic distortions induced by the fields of the refractive index was also conducted as part of the study. The ultimate goal was to synthesize an algorithm capable of reconstructing the entire wave front information based on the actual data taken from an 18-mile optical communication link recently established between AFRL in Rome, NY and the Air Force testing facility in Stockbridge. The main objective of this extension project is to demonstrate a laboratory prototype of a wave front sensor. It is expected that this project will complement other AFRL-funded research efforts in this area, including the Alpha-Eta transceiver development and a recently tested pointing-acquision-tracking (PAT) system.

Shangping Ren, Illinois Institute of Technology – Beyond Byzantine Faults: Addressing the Dependable Cyber-Physical Systems Challenge

The main goal is to extend the current work on fault/attack tolerant techniques for networked and distributed systems. The extension is in the form of addressing specific fault-tolerant challenges

introduced by the involvement of physical components in emerging Cyber-Physical Systems. Networked computers reside at the heart of systems on which many people now rely, both in critical national infrastructures and in private enterprises. Today, many of these systems are still far too vulnerable to cyber attacks that can inhibit their functioning, corrupt important data, or expose private information. "Fault-tolerance" and "attack tolerance" while maintaining system liveness have become key research issues in the cyber defense research community. This year's summer research has been mainly focused on two areas: (1) how to optimally allocate available resources to tolerate cyber attacks and improve networked computer systems' dependability; and (2) how to efficiently and effectively identify fail-stop faults in cyber-physical systems. We have obtained good research results in these two areas over the summer. In particular, to tolerate faults and cyber attacks, we have developed an algorithm that can optimally utilize available resource to enhance existing systems with maximized dependability. This work has already been submitted to a conference.

James E. Stine, Jr., Oklahoma State University – Fabrication of System on Chip Designs Using Cadence Design Tools

The overall objective of this report is to showcase the procedure and definitions provided for System on Chip (SoC) designs when using Cadence Design System tools. The overall objective is to create an easy and repeatable set of documentation that gives a process whereby anyone can repeat the process with some knowledge of Very Large Scale Integration (VLSI) layout design and digital design principles.

Madjid Tavana, LaSalle University – Fuzzy Multiple Criteria Workflow Robustness and Resiliency Modeling with Petri Nets

The increasing complexity and tight coupling between people and computer systems in military operations has led to improved efficiency and, at the same time, to greater vulnerability due to system failure. Careful management of workflow systems has the potential to minimize operational vulnerability in command and control. Tavana et al. (2011) developed a workflow management framework capable of both modeling structure and providing a wide range of quantitative analysis with high-level Petri nets (PNs). Their framework is based on a sustainability index that captures the concepts of self-protecting and self-healing systems. This index uses crisp numerical values to measure the *robustness* and *resiliency* of the system. However, the observed values of data in real-world military operations are often imprecise or vague. These inexact data can be represented by fuzzy numbers to reflect the decision makers' intuition and subjective judgments. In this paper, we extend the model introduced by Tavana et al. (2011) to a fuzzy framework by proposing a new fuzzy workflow modeling system with PNs. The new model will plot the fuzzy robustness and resiliency measures in a Cartesian coordinate system and derives an overall fuzzy *sustainability index* for the system based on the theory of displaced ideals. The proposed model will also consider multiple criteria (i.e. completion cost, repair cost, and available protection) to produce this fuzzy index.

Lei Yu, State University of New York at Binghamton – Feature Selection for Large-Scale Reinforcement Learning: Improving Generalization in Continuous Action Spaces

Applying reinforcement learning algorithms to very large or continuous state and action spaces can lead to policies that are deficient in several ways. The first is that incorporating irrelevant state information may result in a poor policy. The second is that a learned policy may over fit the experienced states, leading to poor generalization ability. We propose a novel embedded recursive feature elimination algorithm for reinforcement learning that addresses these problems by automatically reducing the size of the state space during learning. Our results show that the algorithm enables the learning of significantly more fit policies in the presence of irrelevant features than without. Furthermore, we show that these policies generalize very well to previously unexplored regions of the state space.

4. EXPENDITURES

Under this contract expenses were billed on a faculty/week basis. The rates for the professors were established by the National Research Council for summer research fellows and are as follows.

4.1. Faculty Labor

Assistant Professor	$1,300/week
Associate Professor	$1,500/week
Full Professor	$1,700/week

Faculty Per Diem: Those faculty members whose home residence/university is more than 50 miles from AFRL/RI were entitled to: $50/day

4.2. Other Costs Associated with Program

Round trip travel reimbursement at the start and completion of the project was provided as requested.

5. LIST OF ACRONYMS

CASE – Center for Advanced Systems and Engineering
STEM – Science, Technology, Engineering and Mathematics
NYSTAR – New York State Office of Science, Technology, and Academic Research
AFRL – Air Force Rome Laboratory
STRIKES – Surgical Test for Rapid Identification of a Known Embedding
LPI/LPD - Low Probability of Interception and Low Probability of Detection
QC – Quantum Communication
QKD - Quantum Key Distribution
KCQ – Keyed Communication in Quantum Noise
PAT – Pointing, Acquisition, and Tracking
LOS – Line of Sight
PDES - Parallel Discrete Event Simulation
VLSI - Very Large Scale Integration
SPFP - Single-Precision Floating Point
BSB - Brain-State-in-a-Box
CR – Cognitive Radio
CC – Central Controller
PEs – Processing Elements
LS – Local Store
SM – Shared Memory
FPGA – Field Programmable Gate Array
ANs – Airborne Networks
IA – Information Assurance
LPs – Logical Processes